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Sampling Larval Populations of the Pandora Moth

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Abstract

Plots and aspects generally contributed significant variation in larval counts in prespray samples, while trees within plots did not. Mean numbers of larvae per branch for each block were not significantly different among sampling designs. Larval counts per branch were not significantly different among three sampling heights. These results are discussed in relation to operational sampling procedures for an outbreak under specific stand conditions.

Keywords: Pandora moth, *Coloradia pandora*

Management Implications

The following guidelines are provided for future sampling during pilot projects or biological evaluations under outbreak conditions: (1) precisely delineate the infestation boundaries, (2) sample 50 plots to achieve a margin of error within 20% of the mean 95% of the time, (3) sample one branch from one tree as a plot, (4) select samples from any aspect but include one north sample in every four samples, (5) select branches 8-10 m above ground, and (6) select foliated, straight branches with a 40- to 60-cm tip which does not fork.

Introduction

Sampling techniques for the pandora moth, *Coloradia pandora* Blake, Lepidoptera: Saturniidae, have not been developed. A current infestation on the Kaibab Plateau near Jacob Lake, Ariz., provided an opportunity to sample larvae on ponderosa pine, *Pinus ponderosa* Douglas ex Lawson, using different combinations of trees per plot and branches per tree. Our objectives were to (1) determine the sources of significant variation in larval counts for each sampling design, (2) compare the relative precision of each design, and (3) determine the most efficient sampling design for future projects.

Study Area

The Kaibab Plateau is an essentially flat-topped ovoid 32 km wide and 97 km long with its long axis lying NNW-SSE. The topography is gently rolling and dissected by numerous narrow draws. Elevations range from 2,250 m to 2,760 m, with the elevation at Jacob Lake being 2,376 m. The plateau is generally higher at its center and slopes downward in all directions. Ponderosa pine is the predominant tree species in the area and comprises from 51% to 100% of the infested stands. The stands of ponderosa pine were two or three storied, and were relatively homogeneous with respect to height within each story. Stand density of the dominant trees was relatively homogeneous, but the density of trees 8-17 m tall was not always uniform.

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The current pandora moth infestation was first observed in 1978. By the end of June 1979, more than 1,012 ha had been completely defoliated; 970 additional hectares suffered moderate defoliation. Egg mass evaluations in 1980 indicated the 1981 defoliation area would be at least double the 1979 defoliated area. Egg masses and larvae were observed on all sizes of trees, but larvae seemed to be less abundant on trees in the draws.

In preparation for a pilot project, Forest Pest Management of the Southwestern Region, USDA Forest Service, identified eight blocks within the infested area. Five blocks (blocks 1-5) were sprayed, and three blocks (blocks 6-8) served as checks; all ranged from 200 to 285 ha. Further information on block locations is available in the "Pandora Moth Pilot Control Project Using Acephate—1981" by Forest Pest Management, Southwestern Region, USDA Forest Service, Albuquerque, N. Mex.

Pandora Moth Life Cycle

The pandora moth generally has a 2-year life cycle in the study area. Adults were very abundant in August 1980, and females deposited egg masses on the foliage throughout the crowns. Eggs began hatching in late September, although the majority hatched the first two weeks in October 1980. Larvae fed on foliage on the tips of the branches in October and during exceptionally mild days in the winter months, but the significant defoliation occurred from April to June 1981, when the larvae were reaching maturity. The larvae pupated in the litter and first 3- to 5-cm of soil in June and July 1981, and adults are expected to emerge in August 1982.

Methods

During May 8-14, 1981, prior to the spraying, various combinations of trees per plot and branches per tree (table 1) were sampled on 15 plots ca. 60-100 m apart in each block. The five sampling designs used were (1) four branches from each of three trees per plot (3T-4B), (2) two branches from each of three trees per plot (3T-2B), (3) one branch from each of three trees per plot (3T-1B), (4) one branch from each of six trees per plot (6T-1B), and (5) four branches from one tree as a plot (1T-4B). For the 6T-1B design, data from one branch from each tree in the 3T-2B design were coupled with the data from the 3T-1B design. Branch tips, 30-70 cm long, were pruned from mostly 8- to 17-m-tall ponderosa pine with well developed crowns. Occasionally taller trees had to be sampled because 8- to 17-m trees were not available. This taller tree sampling was rare; when necessary, samples were drawn from the same height as from the 8- to 17-m trees. The branch tips were generally well foliated and consisted of a main stem with several lateral shoots. However, in blocks 2 and 4, where many trees were completely defoliated in 1979, the branches were sparsely foliated and appeared to be more forked than in other areas. Tips were pruned into a basket on a pole pruner. Larvae were counted, and branch length along the primary stem was measured. The number of larvae per branch was subjected to analysis of variance testing for significant variation among plots, trees within plots, and aspects for each block, $P = 0.05$.

From May 27 to May 31, 1981 (15 days after spraying), samples were collected in the blocks in the previously described manner, except that only the 3T-2B and 3T-1B methods were used. Larval numbers were subjected to analysis of variance testing for significant variation among plots and trees within plots, $P = 0.05$.

To determine the vertical distribution of larvae on trees ca. 14 m tall, branch samples were pruned from ca. 5, 8, and 12 m above ground on a specific aspect. Branchlets were pruned from 16 trees in block 3 and 20 trees in block 8 on May 11 and May 13, 1981, respectively. Number of larvae per branch was analyzed for significant variation among heights, $P = 0.05$.

Table 1.—Number of blocks, plots, trees, branches, and aspects sampled for pandora moth larvae

Date	Block	Plots	Trees per plot	Branches per tree	Aspects	Height above ground
						m
May 8-10, 1981	3,4,8	15	3	4	N,E,S,W	6-10
		15	3	1	No specific direction	6-10
		15	1	4	N,E,S,W	6-10
May 12-14, 1981	1-8	15	3	2	N-S,E-W	6-10
			3	1	No specific direction	6-10
May 11, 1981	3	16	1	3	N,E,S,W	5,8,12
May 13, 1981	8	20	1	3	N,E,S,W	5,8,12
May 28-31, 1981	1-8[a]	15	3	2	N-S,E-W	6-10
		15	3	1	No specific direction	6-10

[a]*These data represent samples taken 15 days after spraying.*

Where there was significant variation among aspects or among crown levels, Tukey tests were performed to determine which means were significantly different, $P = 0.05$.

Results and Discussion

Larval Numbers Per Branch

The mean number of larvae per branch ranged from about 1 to 4.5 in prespray samples and from 0.25 to 2.8 in postspray samples (tables 2, 3). Mean numbers per branch within the same block were not significantly different among sampling methods in prespray and postspray samples.

Mean numbers per branch increased insignificantly with height, which indicates any height may be sampled. Mean numbers were similar and exhibited the same trend as indicated in the following tabulation.[4]

Height above ground	Block 3	Block 8
m	$\bar{X} + SD$	
12	4.4a ± 4.1	4.7a ± 3.0
8	3.6a ± 3.1	4.2a ± 3.7
5	2.3a ± 2.1	3.0a ± 2.9

Larval counts ranged from 0 to 29. Count data exhibited similar trends among the three blocks (fig. 1), which indicates the homogeneity among the three blocks. When the data for the three blocks was pooled to represent the distribution of counts for the population, the counts approximated the Neyman Type A distribution. However, the pooled data trend is misleading because it includes zero counts created by topographical influences which are inherent in the counts for the three blocks, especially block 8. If the zero counts are excluded (see sources of variation in larval numbers), the distribution of counts for the population was probably similar to the distribution for block 3.

Sources of Variation in Larval Numbers

The 3T-4B method was the only method where the contribution of plots, trees within plots, and aspects to the variation in larval numbers could be tested simultaneously. With it, plots and aspects contributed significant variation in larval numbers in two of three blocks (table 4). Trees within plots contributed significant variation only in block 4. The plot-tree interaction was significant in two of three blocks.

[4]*Means followed by the same letter are not significantly different,* P = *0.05.*

Table 3.—Mean number of larvae per branch for prespray and postspray samples, May 12-14 and 29-31, 1981

Time of sample Block number	Sampling design 6T-1B	3T-2B	3T-1B
	$\bar{X} \pm SE$		
Prespray			
1	3.6 ± 0.20	3.2 ± 0.27	3.8 ± 0.29
2	2.9 ± .35	3.2 ± .49	2.9 ± .32
3	3.0 ± .39	3.1 ± .27	2.7 ± .39
4	1.3 ± .14	1.1 ± .14	1.2 ± .20
5	3.4 ± .43	3.4 ± .55	2.8 ± .42
6	3.4 ± .37	3.1 ± .33	3.4 ± .40
7	2.4 ± .24	2.7 ± .29	2.3 ± .31
8	2.8 ± .53	2.9 ± .51	2.9 ± .68
Postspray			
1	2.7 ± .24	2.8 ± .31	2.6 ± .30
2	2.4 ± .31	2.3 ± .31	2.4 ± .41
3	1.7 ± .26	1.4 ± .20	1.6 ± .36
4	0.3 ± .07	0.4 ± .10	0.2 ± .08
5	1.4 ± .26	1.3 ± .28	1.6 ± .29
6	2.6 ± .33	2.5 ± .37	2.3 ± .24
7	2.5 ± .27	2.4 ± .28	2.4 ± .35
8	2.1 ± .44	2.2 ± .44	1.8 ± .45

The other sampling methods had similar sources of significant variation. Prespray sampling with either the 3T-2B or 3T-1B method showed plots contributing significant variation in two of eight blocks (table 4). Trees within plots contributed insignificant variation in every block with either method, which indicates the homogeneity of the infestation with respect to the host.

Postspray sampling with the 3T-2B method resulted in plots contributing significant variation in all blocks, while with the 3T-1B method, plots contributed significantly in two of eight blocks (table 4). Trees within plots contributed significantly in one block under each method.

Significant variation among plots in prespray and postspray samples originates from the influence of topography or site on larval densities. In block 8, for example, most of the plots were on the flat ridgetop, while some were off the ridge in adjacent, lower-elevation drainages. Larvae were abundant on ridgetops but were absent in the lower elevation plots in draws and hence created significant variation among plots. Moth ovipositional behavior may account for the differences, but this is not certain.

Table 2.—Mean number of larvae per branch for prespray samples, May 8-10, 1981

Block number	Sampling designs 3T-1B	3T-4B	3T-2B N-S	3T-2B E-W	1T-4B
	$\bar{X} \pm SE$				
3	4.5 ± 0.71	3.6 ± 0.44	4.4 ± 0.70	2.7 ± 0.43	3.6 ± 0.44
4	2.0 ± .49	1.3 ± .14	1.4 ± .15	1.2 ± .22	1.6 ± .29
8	3.4 ± .52	4.2 ± .47	4.9 ± .63	3.5 ± .39	4.2 ± .61

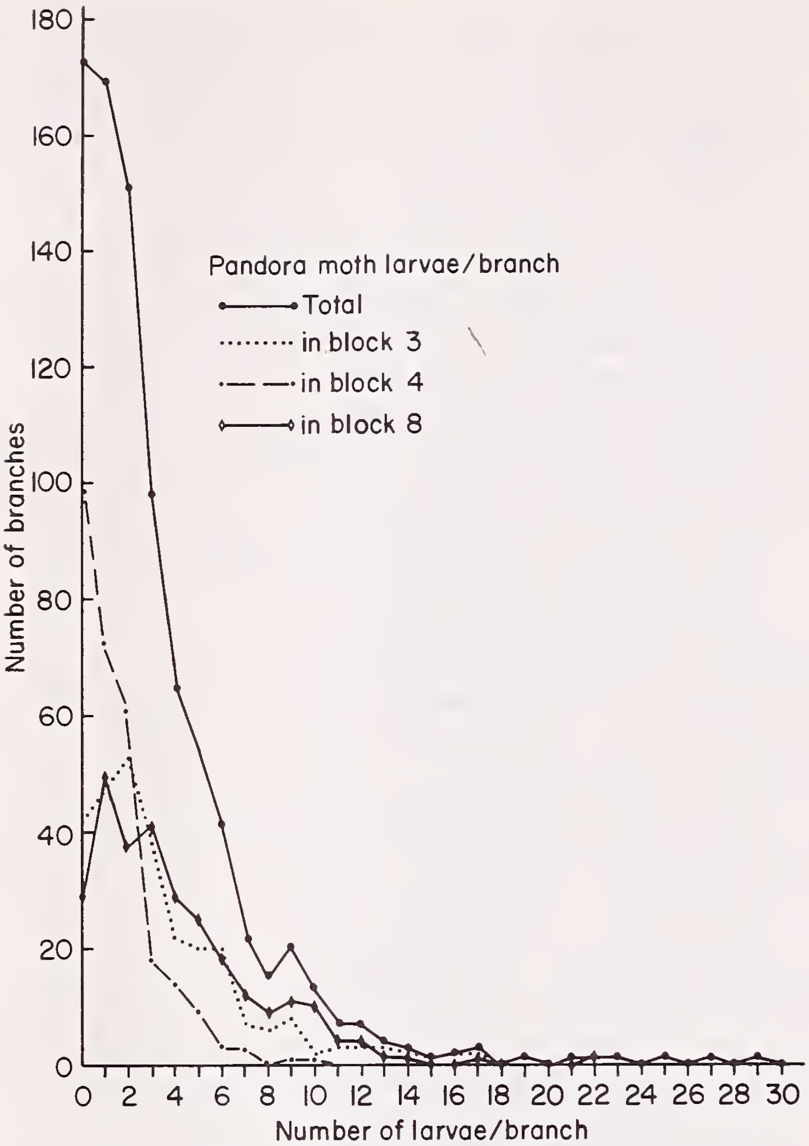

Figure 1.—Frequency diagram for larvae per branch.

Insignificant variation among trees within plots in most blocks indicates moths oviposit equally on all trees of the size sampled, and/or larvae survive equally well on all trees at the sample heights. The significant variation among trees within plots in block 4 reflects previous defoliation and tree vigor. Trees therein were severely defoliated in 1979. Some recovered better than others, so their foliage was more abundant and greener. These trees either sustained greater egg deposition or larval survival. In any case, larvae were more abundant on them, but the variable densities created significant differences among trees within plots.

Significant variation associated with aspects was caused by the larger counts on the north sides. This fact is not readily explainable and needs further research. Its effect on sampling is discussed in the section on sampling implications.

Sampling Implications

These data and observations during the sampling period suggest guidelines for future operational surveys or biological evaluations of pandora moth larval populations:

1. Delineate infestation boundaries before sampling and then confine the sample plots or trees to the infested area. Larvae will be absent from some trees and, perhaps, from a few plots just by chance, so a few zero counts are to be expected. However, most zero counts in this study were primarily caused by plots being established on sites where larvae were

Table 4.—Sources of variation in larval numbers

Time of sample / Sampling method / Source of variation	Block number							
	1	2	3	4	5	6	7	8
Prespray								
3T-4B								
Plots			S	NS				S
Trees			NS	S				NS
Aspects			S	NS				S
Plot-tree interaction			NS	S				S
Plot-aspect interaction			NS	NS				NS
Tree-aspect interaction			NS	NS				NS
3T-2B								
Plots	NS	S	NS	NS	NS	NS	NS	S
Trees	NS	NS	NS	NS	NS	NS	NS	NS
Plot-tree interaction	NS	NS	NS	NS	NS	S	NS	NS
3T-1B								
Plots	NS	NS	S	NS	NS	NS	NS	S
Trees	NS	NS	NS	NS	NS	NS	NS	NS
1T-4B								
Trees			NS	S				NS
Aspects			NS	NS				NS
Postspray								
3T-2B								
Plots	S	S	S	S	S	S	S	S
Trees	NS	NS	NS	NS	NS	NS	NS	S
Plot-tree interaction	S	NS	NS	S	NS	NS	NS	S
3T-1B								
Plots	NS	NS	S	NS	NS	NS	NS	S
Trees	NS	NS	NS	S	NS	NS	NS	NS

S = Significant at 0.05
NS = Nonsignificant at 0.05

not present, particularly draws. Even though such sites were within gross infestation boundaries, they were not within the actual infestation area, so that data from such sites created unnecessary variation. Eliminating unnatural zero count plots will require additional and more accurate work by Forest Pest Management in delineating infestation boundaries and making sure the sample trees are within the infested area, but the precision of the estimate of larval numbers will increase.

2. When larval counts average two to four larvae per branch, sample 50 plots to achieve a mean with a 20% margin of error ($P = 0.05$). Similarly, if a mean with a 10% margin of error is desired, at least 200 plots should be taken. When larval counts average less than 1.5 per branch, more than 100 plots will have to be taken to derive a mean with a 20% margin of error.
3. Sample one branch from one tree as a plot, with the sample trees being systematically located throughout the infested area. Branches within the same sampling height were not generally significantly different (see discussion in (4) below), so this method would be as accurate as the other methods. Furthermore, costs for this method would be less than costs for other methods because fewer branches would be taken.

The cluster designs (3T-1B, 3T-2B, etc.) warrant some discussion. These designs consist of a small group of closely spaced sample trees and are primarily used because it is more cost effective to sample a number of trees in close proximity than the same number of widely spaced trees. They assume the sample trees are from a homogeneous stand.

For many plots in this study, stand and tree conditions prevented selection of three or more trees in close proximity; some clusters had distances of 40 m or more between the trees. Distances of this magnitude violate the cluster sampling concept and eliminate its cost effectiveness. More importantly, the insignificant variation among trees within plots and the between-tree distance suggests that cluster sampling is less efficient for this insect under these stand conditions. If it is used, the 3T-1B method would be most cost effective.

4. Select branches from any aspect, but include only one branch from the north in every four samples. Larval numbers on the north sides were significantly greater than on the other three aspects, which were not different from each other. If only north samples are taken, mean larval numbers will be overestimated. If all samples are drawn from the east, south, and west sides, mean larval numbers will be underestimated. Thus one north sample should be included in every four samples.
5. Select branches about 8-10 m above the ground. Larval numbers per branch increased insignificantly with height, so sampling at any height within 5 to 12 m off the ground will not affect the estimate. However, these large larvae can be easily seen at 5 m, so branches should be selected at greater heights in order to reduce the bias of selecting branches with larvae.
6. Select straight, foliated branches which will have a 40-60 cm tip without excessive branching. Reject branches < 40 cm, > 60 cm, or with excessive side branches. Branches without excessive side branches are preferable because they reduce variation in larval numbers created by the presence of additional larvae on irregular and forked branches. A branchlet of 40-60 cm is preferable because it will generally have adequate numbers of larvae and will fit into the basket on the pole pruner. While larval numbers were not correlated with sample length, maintaining consistent sample length will reduce the variation attributable to it. Branch length is somewhat unimportant and misleading because the foliage was not always present throughout. Samples were frequently cut at the inner termination of the foliage even though their length was then shorter than desired. Additional length could have been obtained, but it would have included bare stem which contained no larvae. This type of sample cannot always be avoided because previously defoliated trees frequently appear this way. In those cases, collectors must judiciously select trees which appear to have the most foliage.

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